# CONAXIS – EXAMPLE 3

## Modelling unit cell with stress-dependent parameters

### 1. Problem description

In this example, we deal with a typical soft soil treatment problem using prefabricated vertical drains (PVDs) and vacuum pumping (Table 1).

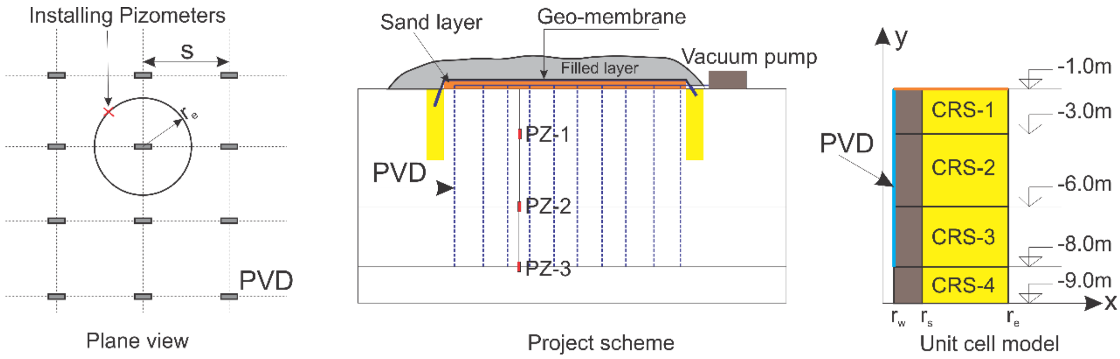


**Figure 1: Model scheme**

A project has a 9.0m layer of the soft soil that is divided into 4 layers. The constant rate of strain tests are conducted for each layer, namely CRS-1, CRS-2, CRS-3, CRS-4. To improve the shear strength of soil, the treatment method is to combine the vacuum pumping, the surcharge loading, and PVDs.

The construction process is given in Table 1, and the soil properties is given in Table 2.

**Table 1: Construction process**

| Tasks | From (day) | To (day) | Duration (day) |
|---|---|---|---|
| Installing PVDs | 0 | 10 | 10 |
| Filling 0.5m sand layer | 10 | 15 | 5 |
| Pumping vacuum (80kPa) | 15 | 115 | 100 |
| Filling 2.0m compensation layer | 50 | 100 | 50 |

**Table 2: Soil properties**

| Layer | Thickness (m) | Unit weight (kN/m3) | Void ratio | Ratio $k_h / k_v$ | Ratio $k_s / k_h$ |
|---|---|---|---|---|---|
| Layer-1 | 2.0 | 16.4 | 1.6 | 3.0 | 0.33 |
| Layer-2 | 3.0 | 15.2 | 1.841 | 3.0 | 0.33 |
| Layer-3 | 2.0 | 15.7 | 1.810 | 3.0 | 0.33 |
| Layer-4 | 1.0 | 15.9 | 1.823 | 3.0 | 0.33 |
| Sand layer on the top | 0.5 | 20 | - | - | - |
| Filled layer | 2.0 | 20 | - | - | - |

The length of PVD is 7.0m. Assuming that it takes 8 days to reach -80 kPa vacuum, and then the vacuum is kept for the whole process. By using excel, we calculate values of surcharge loading and vacuum pressure that depend on the construction time and save them as *surcharge.dat* and *vacuum.dat* file.

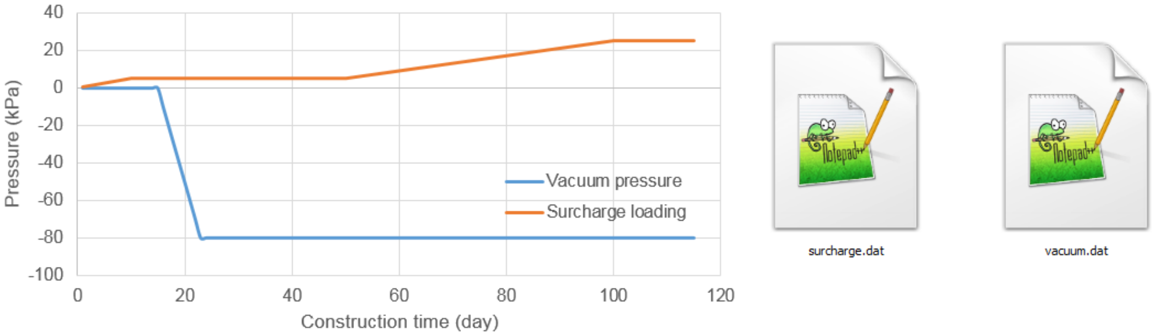


**Figure 2: Surcharge loading and vacuum pressure over time**

Three piezometers are installed at the elevation of -3.0m, -6.0m, and -8.0m (Figure 1).

The size of PVD is $100 \times 4mm$ and the size of the mandrel is $120 \times 60mm$. Hence, the equivalent radius of the PVD is:

$$r_w = \frac{0.5b + 0.7t}{2} = \frac{0.5 \times 0.1 + 0.7 \times 0.004}{2} = 0.0264\ m$$

The smear zone is twice as the mandrel size, the equivalent radius of the smear zone is:

$$r_s = 2 \times \frac{0.5 \times 0.12 + 0.7 \times 0.06}{2} = 0.102\ m$$

PVDs are installed with a rectangular pattern. The distance between each PVDs is $s = 1.0m$ . Hence, the radius of the unit cell is: $r_e = 0.565 \times s = 0.565m$.

For this analysis, we need to find:

- The settlement of the surface over time.
- The development of excess pore pressure of the Piezometers.

## 2. Step 1: Back-analysis

Data of CRS tests are saved as *CRS-1.dat*, *CRS-2.dat*, *CRS-3.dat*, *CRS-4.dat*. Following the example-2, we do the back analysis with the following input parameters:

- The initial height of sample: $H_0 = 0.0254m$
- The radius of the sample: $R = 0.03175cm$
- Poisson's ratio: $\upsilon = 0.35$

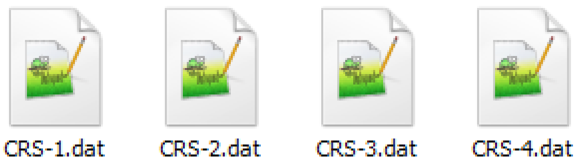


**Figure 3: Data of CRS tests**

After the back analysis process, we obtain results as *CRS-1-BA.dat, CRS-2-BA.dat, CRS-3-BA.dat, CRS-4-BA.dat.*

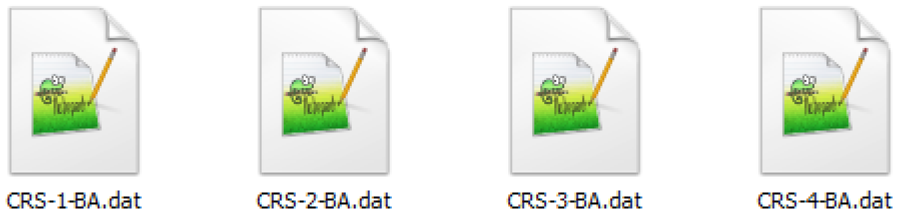


**Figure 4: Results after back analysis**

## 3. Step 1: Create a mesh

Click *Geometry/Create mesh*. We input information as Figure 5.

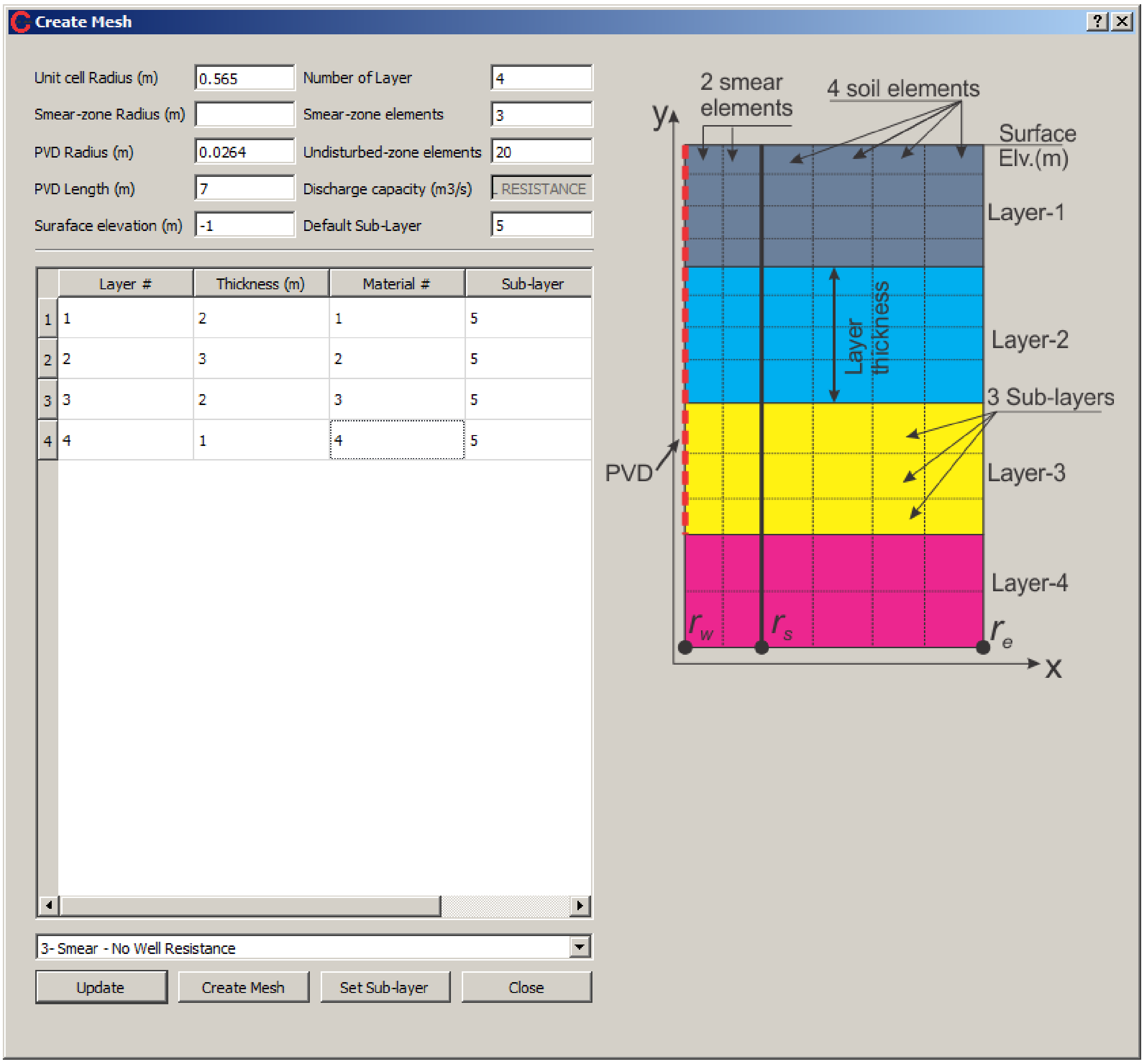


**Figure 5: Parameters to create the mesh.**

Click *Update* and *Create Mesh*. The mesh will be displayed on the main window. To have a better view, click *Plot Control / Pick Result and Scale Setting*, and put 5.0 to *X-coordinate scale*. The final mesh looks like Figure 6. Different colours represent different layer.

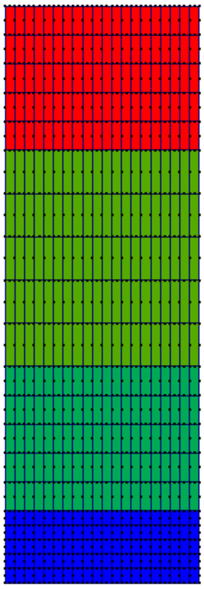

**Figure 6: The mesh after scaling the x-direction five times**

## 4. Step 2: Defining material

Click *Material / Create Material.* For the Material #1, choose the bulk modulus type as Figure 7. Then a dialog pops out and we browse to the file *CRS-1-BA.dat.* Repeating with the hydraulic conductivity.

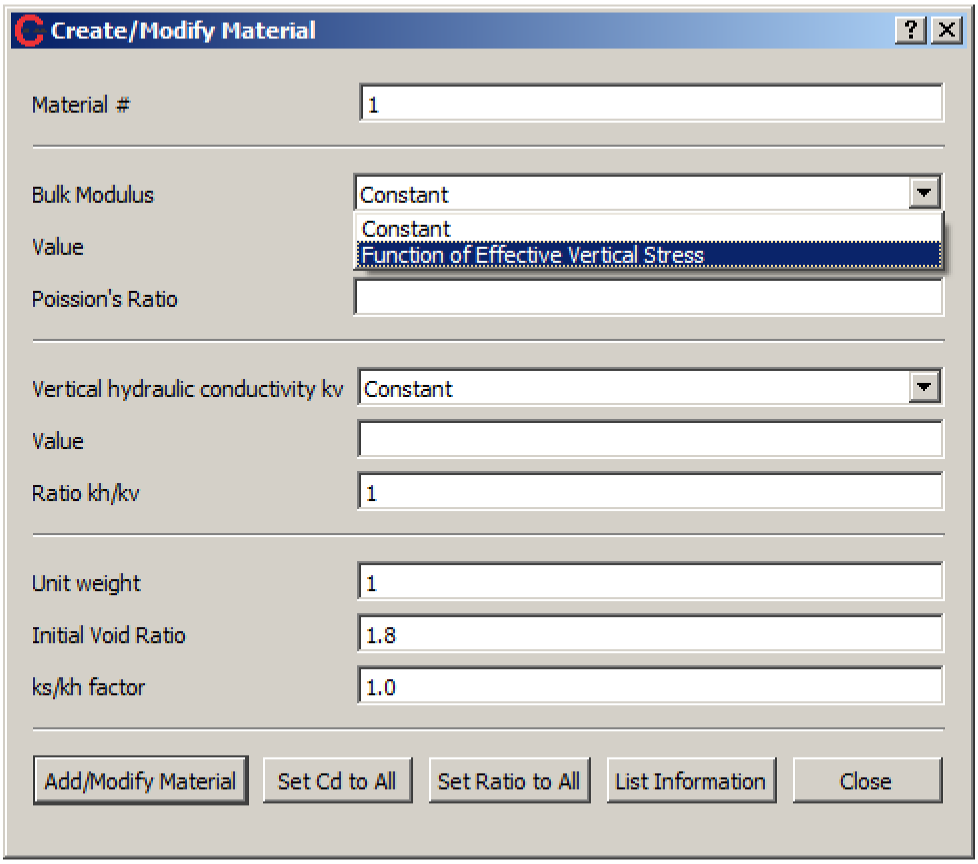


**Figure 7: Choosing bulk modulus type and vertical hydraulic conductivity type**

The other information is taken from Table 2. It is noted that the unit weight is the buoyant unit weight.

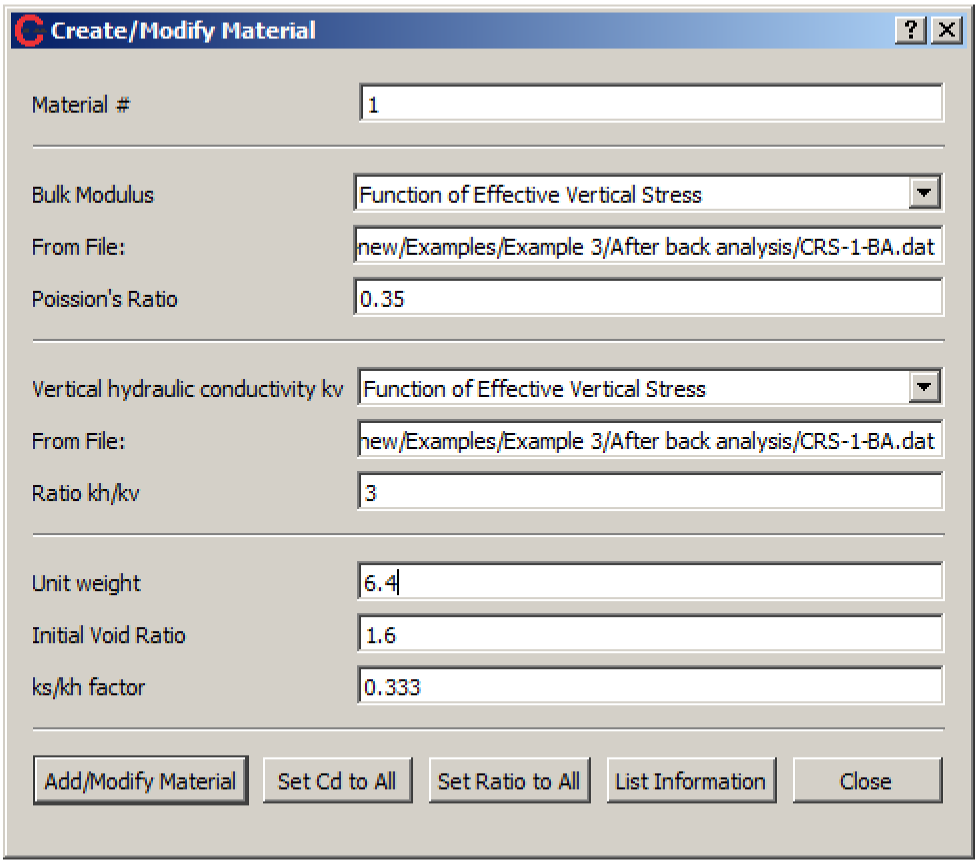


**Figure 8: Material #1**

Repeating with Material #2 (Figure 9), Material #3 (Figure 10), and Material #4 (Figure 11).

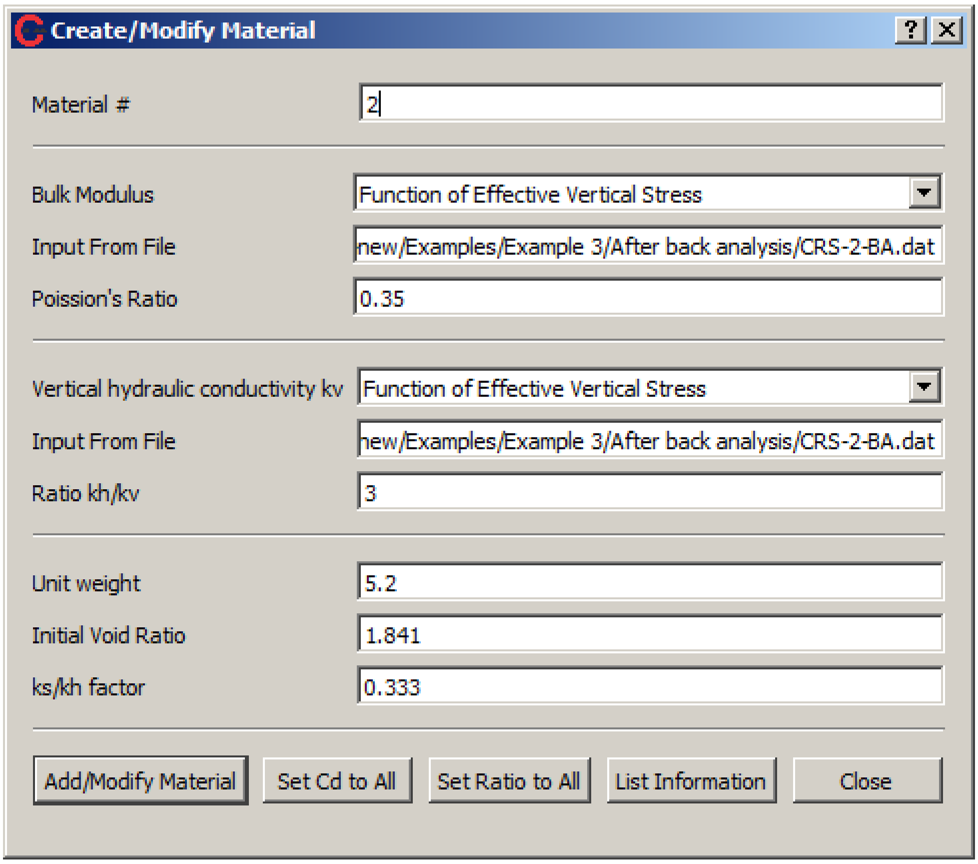


**Figure 9: Material #2**

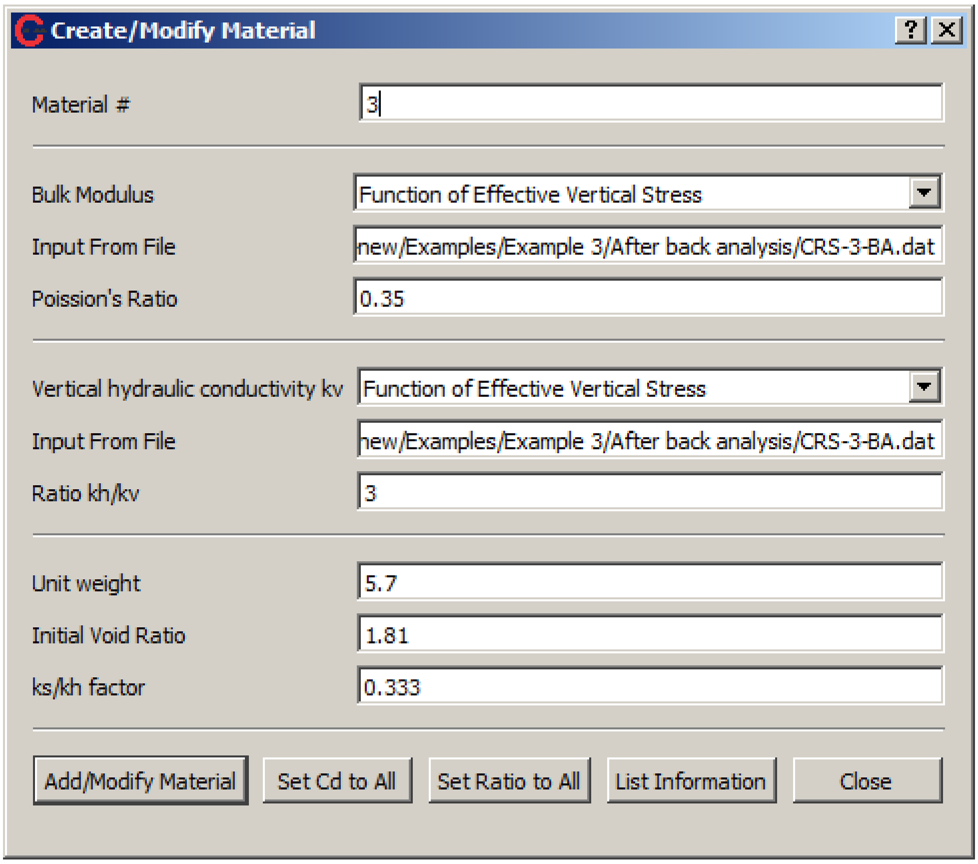


**Figure 10: Material #3**

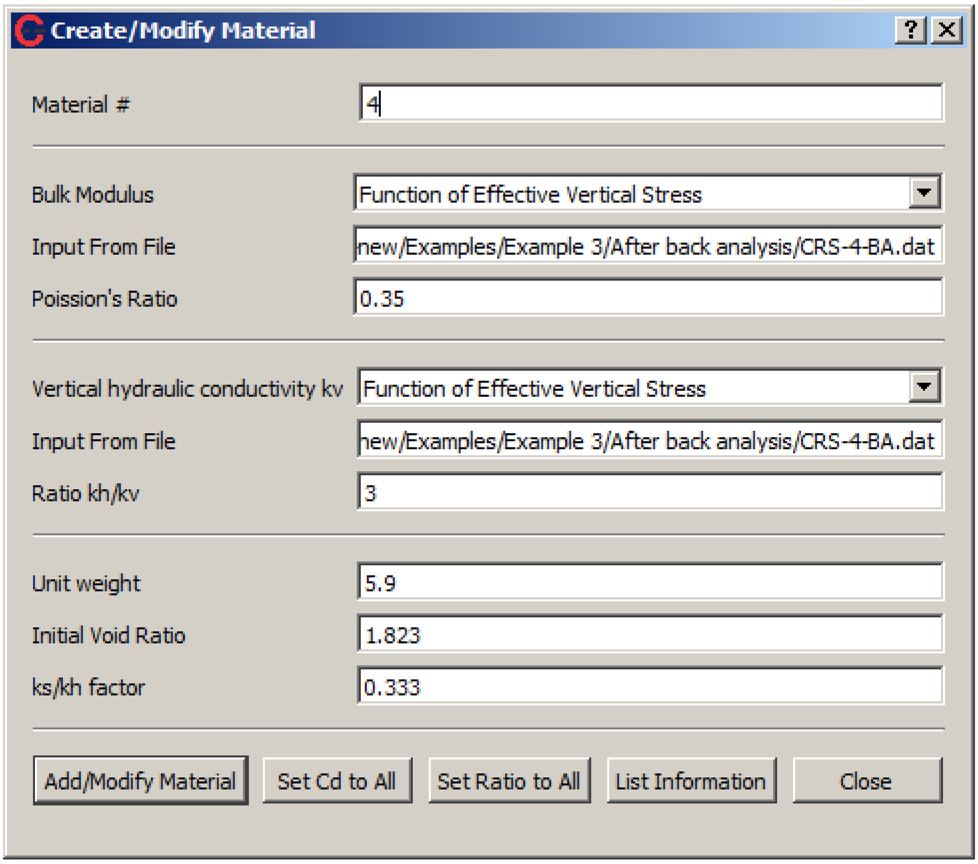


**Figure 11: Material #4**

### 5. Step 3: Defining analysis stages

For this analysis, we have three stages (Table 3):

- **In-situ:** To generate the field stress. For this stage, the gravity load is included.
- **Before installing PVDs:** There is only vertical flow. However, there is no surcharge loading yet, hence we expect that nothing happens in this stage.
- **Filling sand layer:** The PVD boundary is set to drained, excess pore pressure is zero.
- **Vacuum pumping:** The PVD boundary and top boundary are assigned vacuum pressure (excess pore pressure is negative).

**Table 3: Analysis stages**

| Stage | Start (day) | Duration (day) | Sub-step |
|---|---|---|---|
| In-situ | 0 | 0 | 1 |
| Before installing PVDs | 0 | 10 | 20 |
| Filling sand layer | 10 | 5 | 10 |
| Vacuum pumping | 15 | 100 | 200 |

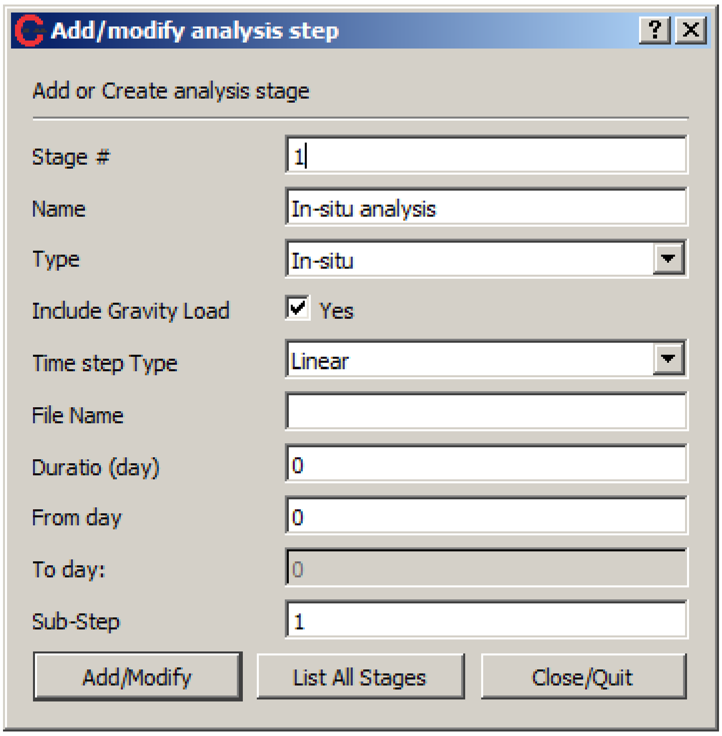


**Figure 12: In-situ**

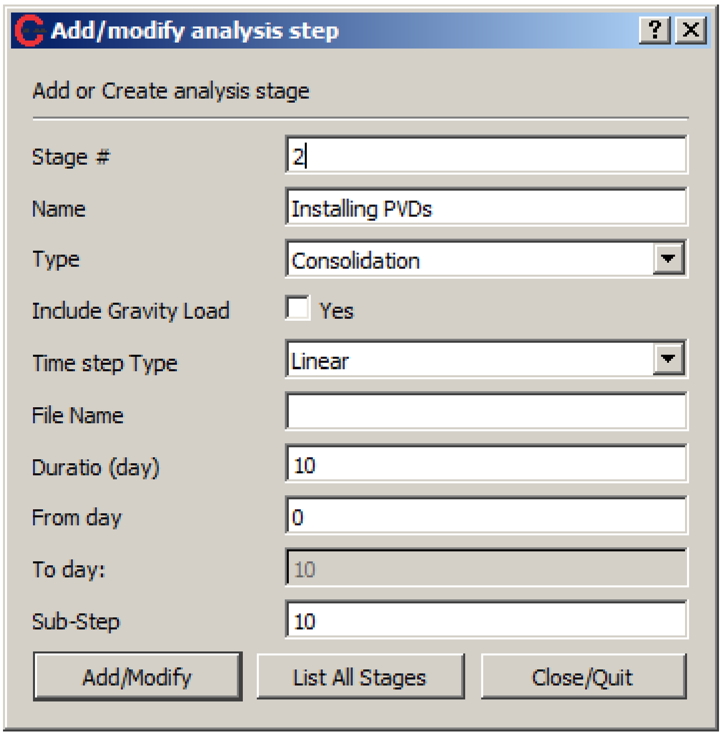


**Figure 13: Installing PVDs stage**

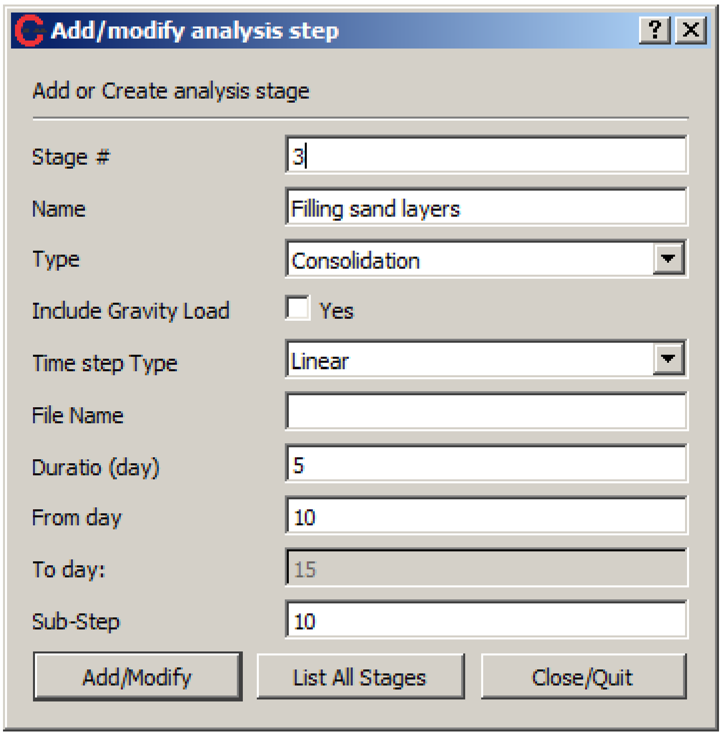


**Figure 14: Filling sand layer**

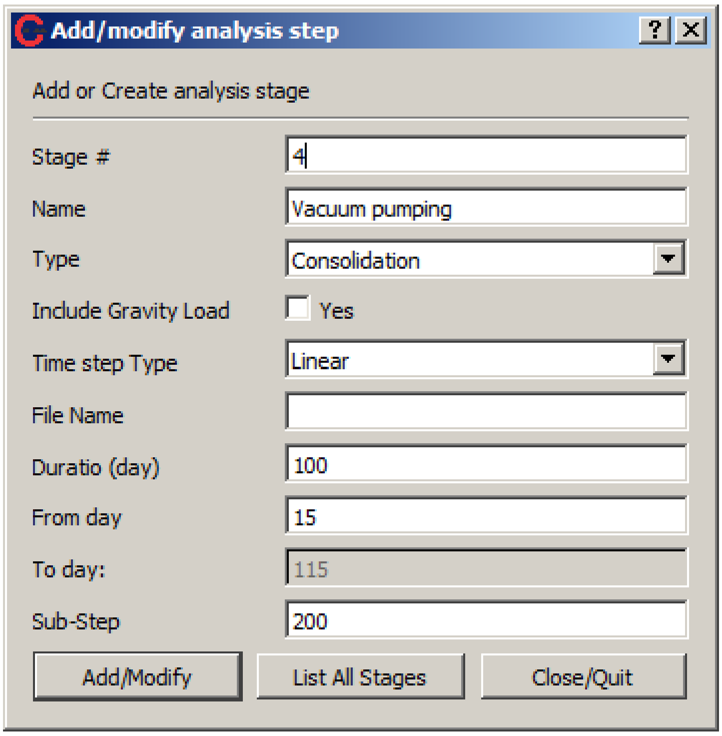


**Figure 15: Vacuum pumping**

## 6. Step 4: Defining boundary conditions

There are five type of boundary conditions for this analysis:

- BC1: No horizontal movement, for the left and the right side of the model.
- BC2: No vertical movement, for the bottom boundary
- BC3: Surcharge loading, for the top boundary
- BC4: Excess pore pressure is zero, for the top boundary and the PVD boundary
- BC5: Excess pore pressure is negative (vacuum)

To create boundary conditions, click *Boundary Condition / Add Boundary Condition.*

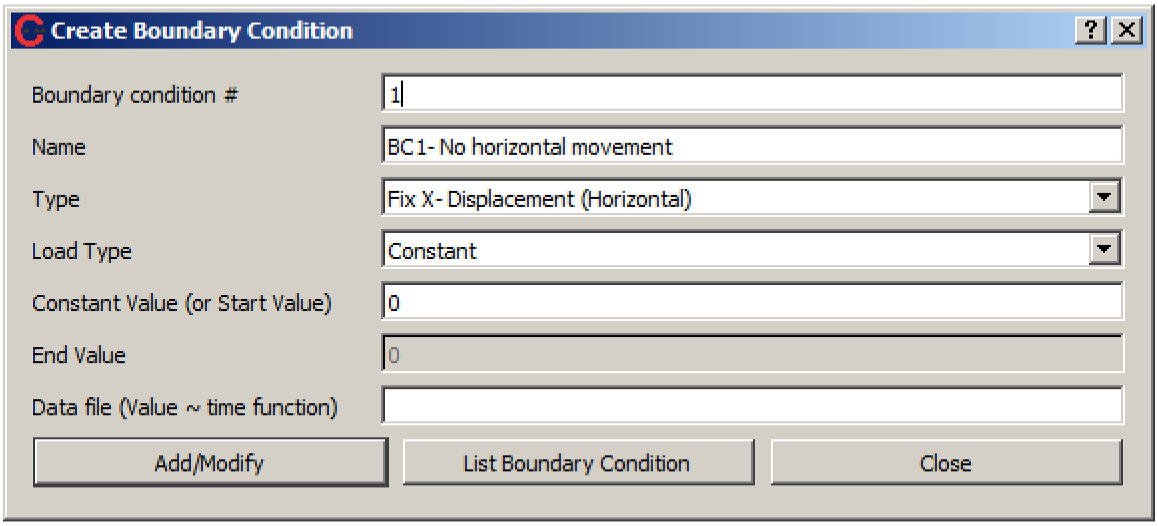


**Figure 16: Boundary condition #1**

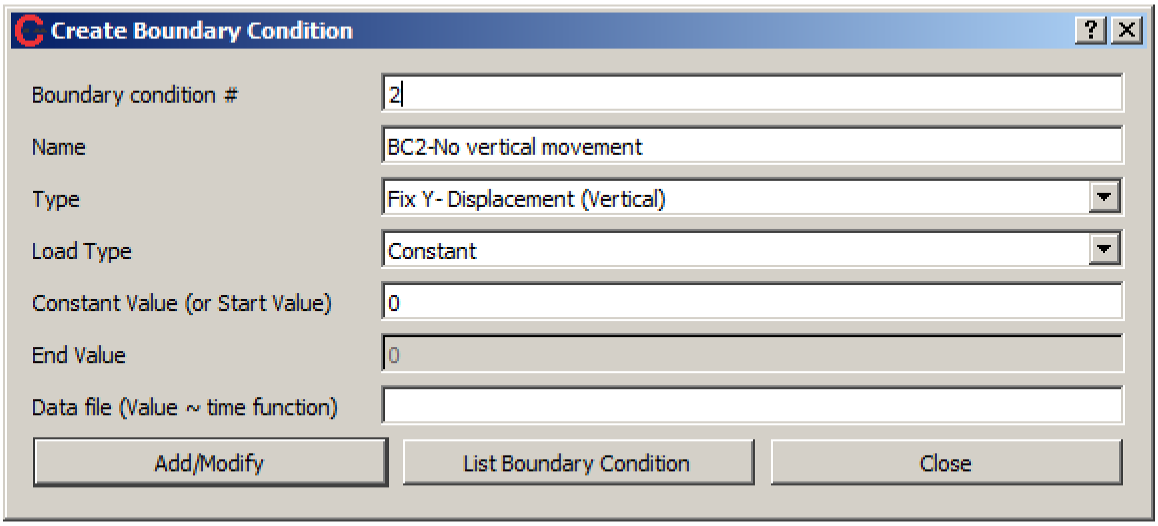


**Figure 17: Boundary condition #2**

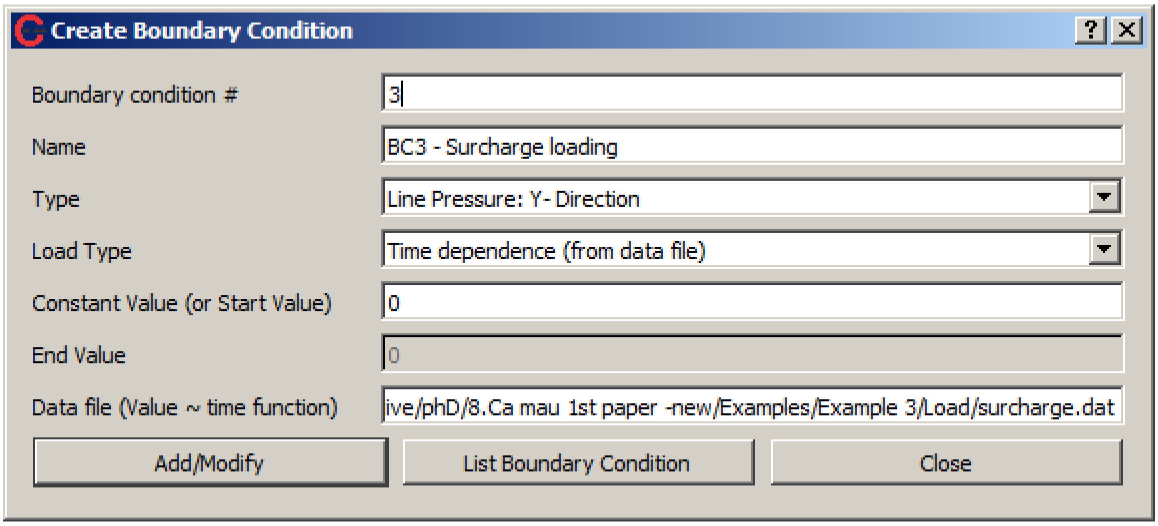


**Figure 18: Boundary condition #3**

For the BC3, values in the file *surcharge.dat* is positive. However, because the direction of the load and the Y-axis is opposite. Hence, values must be scaled with the factor -1.0.

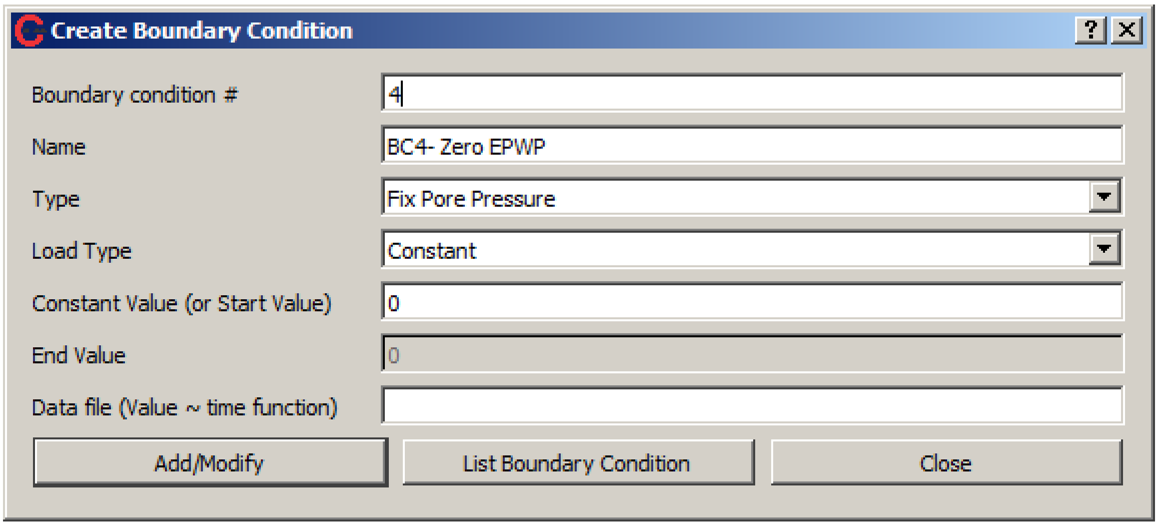


**Figure 19: Boundary condition #4**

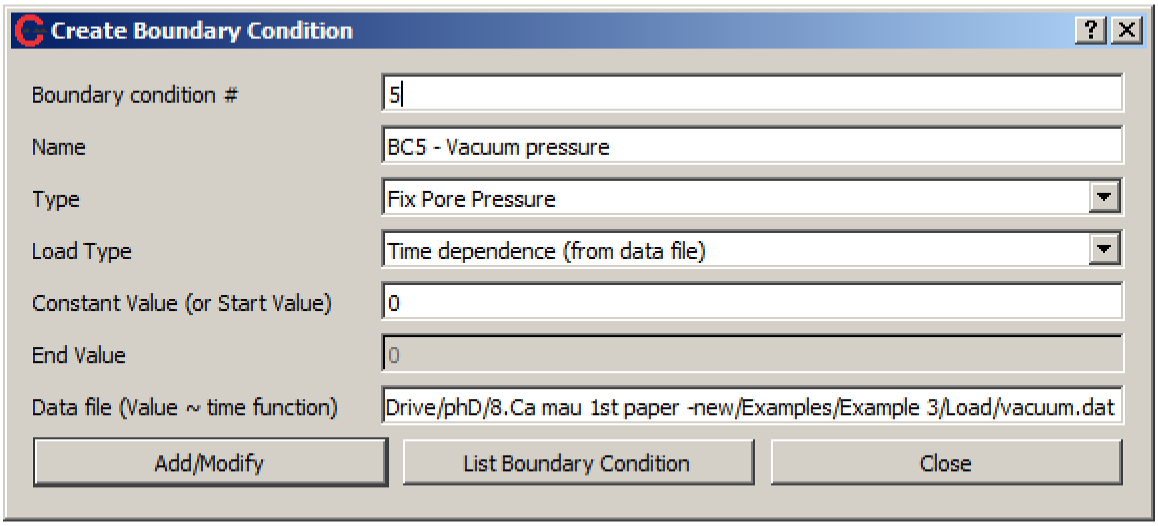


**Figure 20: Boundary condition #5**

## 7. Step 5: Assign boundary conditions to analysis stages

Click *Boundary Condition / Assign Boundary condition.* The boundary conditions are assigned to each stage as Figure 21.

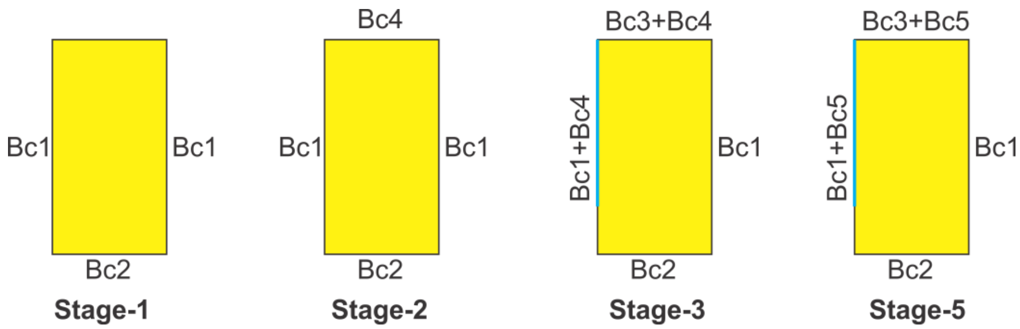


**Figure 21: Boundary conditions for each stage**

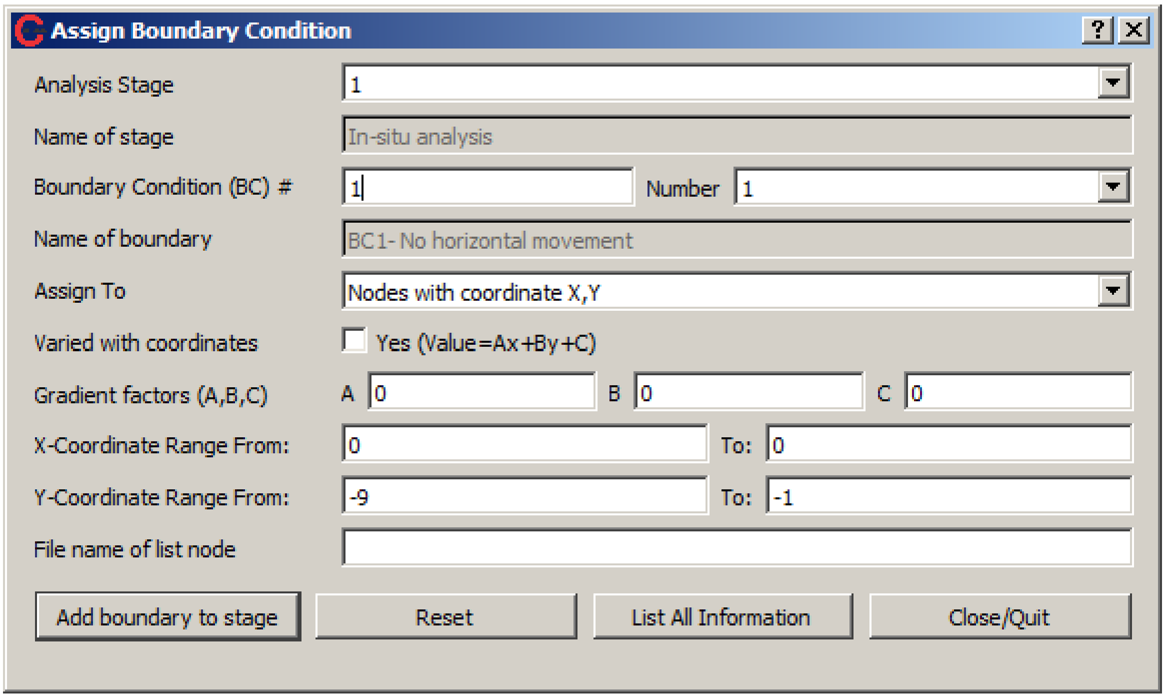


**Figure 22: For instance, assign BC1 to nodes that have x =0, y=-9.0 to y=-1.0 (the left side)**

## 8. Step 6: Defining watch lists

We need to have the settlement over time, and values of the excess pore pressure at piezometer positions. Hence, we create four watch lists *(Solve/ Monitoring points)*

## 9. Stage 7: Run analysis

Click *Run*. The final results are presented in Figure 23.

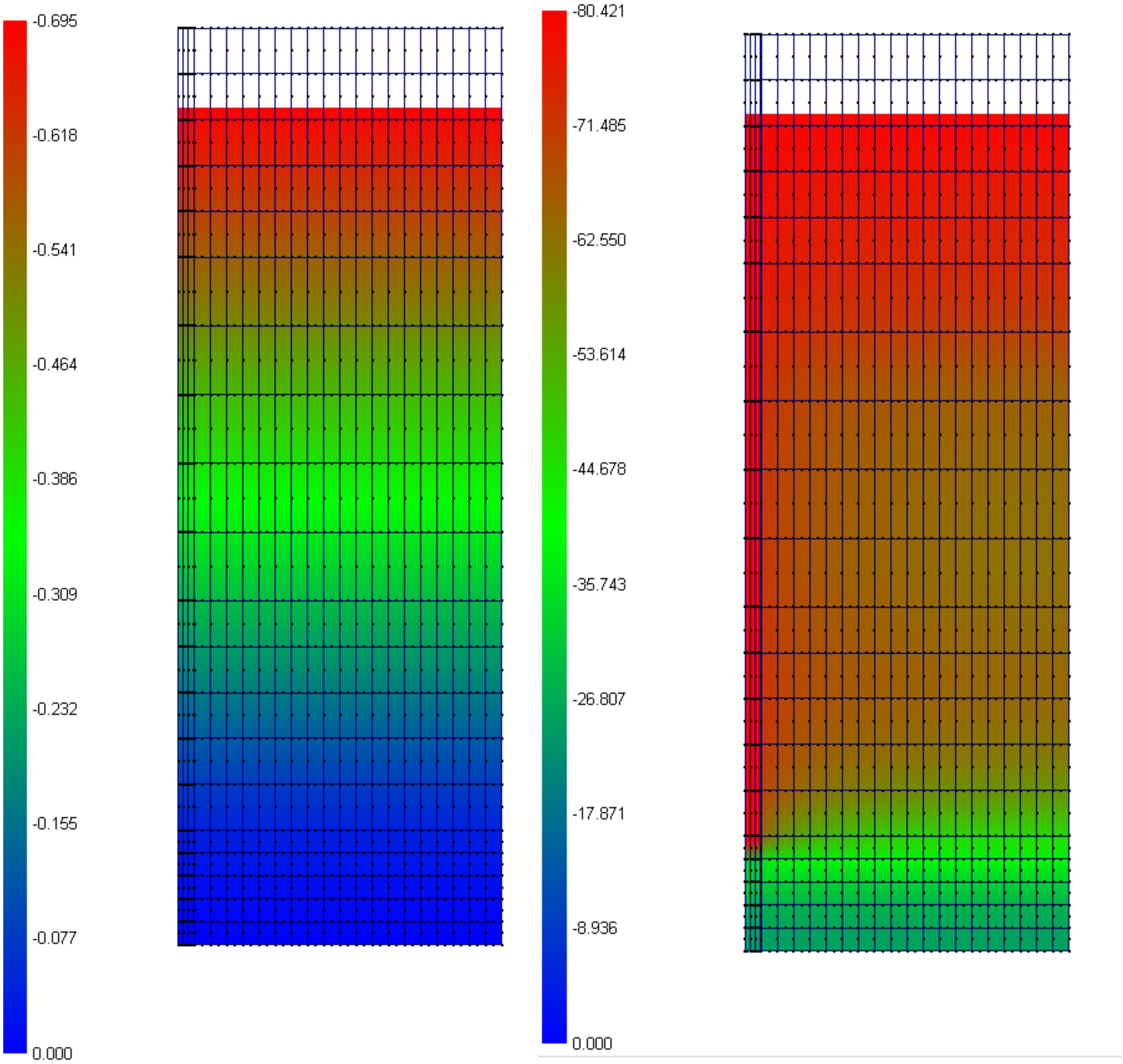


**Figure 23: Final settlement and excess pore pressure**